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Growth of Third-Harmonic Signal in Optical Glass Fibre

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Rapid growth with time of the third-harmonic signal in optical glass fibres, illuminated with 10kW peak power pulses from a Nd:YAG laser, has been observed. Broadband fluorescence from the third-harmonic signal around 420 nm was also detected. Keywords:

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GROWTH OF THIRD-HARMONIC SIGNAL IN OPTICAL GLASS FIBRE

Indexing terms: Optical fibres, Nonlinear optics, Optics, Glass

Rapid growth with time of the third-harmonic signal in optical glass fibres, illuminated with 10kW peak power pulses from a Nd : YAG laser, has been observed. Broadband fluorescence from the third-harmonic signal around 420nm was also detected.

Efficient second-harmonic generation (SHG) has been observed in optical fibres.[1] The most significant part of this observation is that the amount of SH light is very small to begin with (due to the amorphous nature of glass) but with time, as the fibre is illuminated with intense laser light at $\lambda = 1{\cdot}06\,\mu$m, the SH signal grows. What is believed to happen during this 'preparation stage' is that a periodic $\chi^{(2)}$ nonlinearity is established in the fibre. The periodicity is important for phase-matching. A good review of SHG in optical fibres can be found in Reference 2. Microscopically what is going on during the preparation is still very unclear. In this letter it is reported that for optical fibres which show efficient SHG, occasionally the third-harmonic (TH) signal can grow exponentially with time at the expense of the SH signal.

Our experiments were performed with a *Q*-switched (1200Hz) and mode-locked (76MHz) Nd : YAG laser (Quantronix 416). Peak powers between 1 and 20kW were launched into the optical fibre. The fibre used had a core diameter of $d \simeq 8{\cdot}3\,\mu$m, $\Delta \simeq 0{\cdot}0037$ and a 1·3m% phosphorous content in the core and cladding. The main dopant in the core was GeO_2.

Optical fibre lengths of 5–30cm were used. The output of the fibre was directed into [illegible]nochromator (Jarrel–Ash, model 82-499) in conjunctic[illegible] an optical multichannel analyser (OMA) (EG&G, mo[illegible] PARC-1460 and a detector 1420 with an intensified linear photodiode array). A typical spectrum is displayed in Fig. 1. To exclude any contribution from the strong infra-red (IR) light at $\lambda = 1{\cdot}064\,\mu$m to the visible and UV signals, two BG18 Schott glass filters were mounted in front of the input slit of the monochromator. Apart from blocking the IR light, the filters each had $\simeq 70\%$ transmission for $\lambda = 0{\cdot}532\,\mu$m ($2\omega$) and $\simeq 20\%$ transmission for $\lambda = 0{\cdot}355\,\mu$m ($3\omega$). A spectrum such as the one in Fig. 1 was recorded with an integration time of 2s, a sensitivity of $\simeq 15$ photons/count and a spectral resolution of $\simeq 6$ Å. The peak around 420μm is believed to be due to fluorescence from the TH signal; this peak has been observed by others.[3]

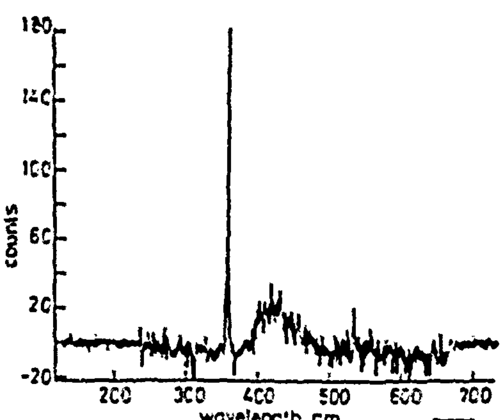

Fig. 1 *Spectrum from 30cm-long unprepared piece of fibre, illuminated with light at $\lambda = 1{\cdot}064\,\mu$m, 10kW peak power*

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For most fibres the SH signal started to grow immediately, and very soon was much larger than the TH signal. The growth rates for the SH signals for different lengths of this optical fibre can be seen in Fig. 1 of Reference 4. For approximately 10% of the fibres investigated, the TH signal started to grow exponentially, with time (Fig. 2).

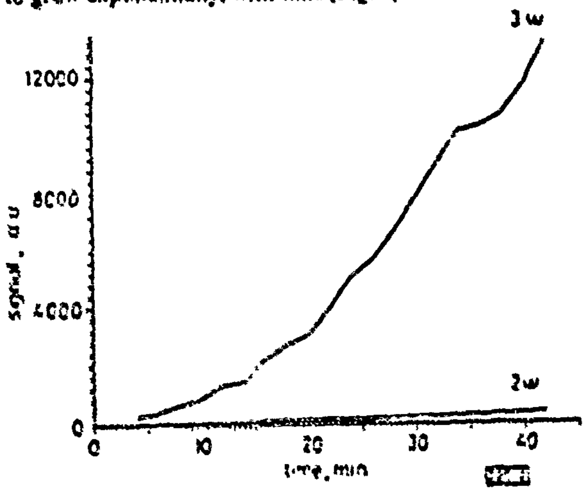

Fig. 2 *Third- and second-harmonic signals as function of illumination time for 5cm-long piece of fibre*

The growth rate for the TH signal was the same as for the SH signal, in fibres where the SH-signal grew and not the TH signal. However, in the cases when the TH signal grew exponentially with time the SH signal grew linearly, and when the TH signal saturated the SH signal started to grow exponentially with time. The saturation level for the TH signal was comparable to the saturation level for the SH signal for this particular length of fibre.

The TH signal grew to approximately 60 times its original value. This increase can be due to growth of the real part of the third-order susceptibility, an increase of the coherence length or both. If the increase could be solely accounted for by an increase in the third-order susceptibility, an increase of a factor of 11 in the spectral width of the fundamental beam should be detected, assuming $\chi^{(3)}(\omega, \omega, -\omega, \omega) \simeq \chi^{(3)}(3\omega, \omega, \omega, \omega)$. Improving our spectral resolution to $\lesssim 1$ Å we could detect no change in spectral width of the fundamental beam before and after the growth of the TH signal. Obviously, more measurements have to be performed before it is known what causes the TH signal to grow.

In conclusion, we report a 60 times increase of the TH signal with time in an optical glass fibre.

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